METHOD AND APPARATUS FOR WIRELESS AUDIO DELIVERY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority of: (i) U.S. Provisional Patent Application No. 60/462,570, filed April 15, 2003, and entitled "WIRELESS COMMUNICATION SYSTEMS OR DEVICES, HEARING ENHANCEMENT SYSTEMS OR DEVICES, AND METHODS THEREFOR," which is hereby incorporated herein by reference; (ii) U.S. Provisional Patent Application No. 60/469,221, filed May 12, 2003, and entitled "WIRELESS COMMUNICATION SYSTEMS OR DEVICES, HEARING ENHANCEMENT SYSTEMS OR DEVICES, DIRECTIONAL SPEAKER FOR ELECTRONIC DEVICE, PERSONALIZED AUDIO SYSTEMS OR DEVICES, AND METHODS THEREFOR," which is hereby incorporated herein by reference; and (iii) U.S. Provisional Patent Application No. 60/493,441, filed August 8, 2003, and entitled "WIRELESS COMMUNICATION SYSTEMS OR DEVICES, HEARING ENHANCEMENT SYSTEMS OR DEVICES, DIRECTIONAL SPEAKER FOR ELECTRONIC DEVICE, AUDIO SYSTEMS OR DEVICES, WIRELESS AUDIO DELIVERY, AND METHODS THEREFOR," which is hereby incorporated herein by reference.

[0002] This application is also related to: (i) U.S. Patent Application No. _____, filed concurrently, and entitled, "DIRECTIONAL WIRELESS COMMUNICATION SYSTEMS," which is hereby incorporated herein by reference; (ii) U.S. Patent Application No. _____, filed concurrently, and entitled, "DIRECTIONAL HEARING ENHANCEMENT SYSTEMS," which is hereby incorporated herein by reference; (iii) U.S. Patent Application No. _____, filed concurrently, and entitled, "DIRECTIONAL SPEAKER FOR PORTABLE ELECTRONIC DEVICE," which is hereby incorporated herein by reference; and (iv) U.S. Patent Application No. _____, filed concurrently, and entitled, "METHOD AND APPARATUS FOR LOCALIZED DELIVERY OF AUDIO SOUND FOR ENHANCED PRIVACY," which is hereby incorporated herein by reference.

FIELD OF THE INVENTION

[0003] The present invention relates to audio systems and, more particularly, to wireless audio delivery from audio systems to personal audio devices.

BACKGROUND OF THE INVENTION

[0004] Audio systems provide audio sounds to one or more users. Audio systems, for example, include stereo systems, DVD players, VCRs, and televisions. These audio systems utilize one or more speakers to provide audio sounds to a wide area. For example, an audio system can be internal to a building (e.g., house) and produce audio sounds from its speakers provided in a particular room. When a user desires to hear the audio output in another room (remote room) far from the audio system, the user is likely unable to hear the audio sounds produced by the audio system. Traditionally, a user would have to provide one or more speakers (e.g., floor, wall, desktop, or book shelve type) in the remote room by running wires from the audio system to the one or more speakers in the remote room. More recently, wireless speakers have become available and can thus eliminate the need to provide such wiring.

[0005] In any case, the audio sounds are provided primarily in the one or more rooms that contains the speakers, and, to a certain degree, to other adjoining rooms. While the ability to hear audio sounds anywhere in the particular room and other adjoining rooms is beneficial if other persons in these rooms desire to hear the audio sounds, unfortunately, however, many times the other persons in the particular room or the adjoining rooms do not desire to hear the audio output. Indeed, these other persons are disturbed by the audio sounds being produced for the enjoyment of others. In effect, to these others, the unwanted audio sounds are a form of noise pollution.

[0006] If the user in the remote room has a headset available, the user can wear the headset to reduce the disturbance to others. The headset needs to be wireless in order to retain mobility. Regardless of whether wired or wireless, wearing

a headset can be uncomfortable and significantly hinders one's ability to hear other sounds.

[0007] Today, there are no satisfactory solutions to reducing such noise pollution. The user (or users) desirous of hearing audio sounds can reduce the volume of the audio sounds or close openings (e.g., doors) to adjoining rooms. These approaches are of limited usefulness as audio sounds pass through doors and walls and reducing volume is often not desirous by the user (or users) desiring to hear the audio sounds. Alternatively, the user desirous of hearing the audio sounds can wear a headset that contains one or a pair of speakers. For example, if the user in the remote room has a headset available, the user can wear the headset to hear the audio sounds instead of using room speakers, and thus reduce the disturbance to others. Wearing a headset is often not acceptable because it substantially limits the user's ability to hear other sounds. When more than a single person is desirous of hearing the audio sounds, often they also want to simultaneously interact with each other or otherwise hear other sounds. However, the use of a headset usually means that only the user can hear the audio sounds (but typically not other sounds) and requires a wired or wireless connection to the audio system. Moreover, as noted above, wearing a headset can often be uncomfortable for the user.

[0008] Thus, there is a need for improved approaches to providing wireless delivery of audio sounds from audio systems to personal audio devices.

SUMMARY OF THE INVENTION

[0009] The invention pertains to techniques for providing wireless delivery of audio sounds from audio systems to personal audio devices. Typically, audio systems are stationary and personal audio devices are portable. These techniques can permit users of the personal audio device to be mobile yet still acquire the audio sounds. Based on the invention, audio systems can be readily adapted to provide the wireless delivery of audio sounds. These techniques can also optionally provide customization (or personalization) of the audio sounds to user's hearing and/or modification of the audio sounds in view of environmental conditions.

[0010] According to one aspect of the invention, audio output from an audio system can be delivered to one or more persons desirous of hearing the audio output. Each person can have a personal audio device. The personal audio device causes audio sound corresponding to audio output from the audio system to be output to its associated person, in a directionally constrained manner. Consequently, other persons not desirous of hearing the audio output do not receive substantial amounts of the audio sounds. Thus, they are less disturbed by the unwanted audio sounds.

[0011] According to another aspect of the invention, a wireless adapter can serve as an after market modification to an audio system. The wireless adapter enables audio signals output by the audio system to be wirelessly transmitted to one or more personal audio devices. Each personal audio device receives the audio sounds and produces audio sound for its user.

[0012] The invention can be implemented in numerous ways, including as a method, system, device, apparatus, and a computer readable medium.

[0013] Other aspects and advantages of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The invention will be readily understood by the following detailed description in conjunction with the accompanying drawings, wherein like reference numerals designate like structural elements, and in which:

[0015] FIG. 1 is a block diagram of a remote audio delivery system according to one embodiment of the invention.

[0016] FIG. 2 is a block diagram of a remote audio delivery system according to another embodiment of the invention.

[0017] FIG. 3 is a block diagram of a remote audio delivery system according to yet another embodiment of the invention.

[0018] FIG. 4 is a diagram of a building layout illustrating use of several embodiments of the present invention.

[0019] FIG. 5 is a flow diagram of a remote audio delivery process according to one embodiment of the invention.

[0020] FIG. 6A is a flow diagram of an environmental accommodation process according to one embodiment of the invention.

[0021] FIG. 6B is a flow diagram of audio personalization process according to one embodiment of the invention.

[0022] FIGs. 7A and 7B are diagrams illustrating an ultrasonic transducer according to one embodiment of the invention.

[0023] FIG. 8 is a perspective diagram of audio systems that provide directional audio delivery to interested users.

DETAILED DESCRIPTION OF THE INVENTION.

[0024] The invention pertains to techniques for providing wireless delivery of audio sounds from audio systems to personal audio devices. Typically, audio systems are stationary and personal audio devices are portable. These techniques can permit users of the personal audio device to be mobile yet still acquire the audio sounds. Based on the invention, audio systems can be readily adapted to provide the wireless delivery of audio sounds. These techniques can also optionally provide customization (or personalization) of the audio sounds to user's hearing and/or modification of the audio sounds in view of environmental conditions.

[0025] According to one aspect of the invention, audio output from an audio system can be delivered to one or more persons desirous of hearing the audio output. Each person can have a personal audio device. The personal audio device causes audio sound corresponding to audio output from the audio system to be output to its associated person in a directionally constrained manner. Consequently, other persons not desirous of hearing the audio output do not receive substantial amounts of the audio sounds. Thus, they are less disturbed by the unwanted audio sounds.

[0026] According to another aspect of the invention, a wireless adapter can serve as an after market modification to an audio system. The wireless adapter enables audio signals output by the audio system to be wirelessly transmitted to one or more personal audio devices. Each personal audio device receives the audio signals and produces audio sound for its user.

[0027] Embodiments of the invention are discussed below with reference to FIGs. 1 – 8. However, those skilled in the art will readily appreciate that the detailed description given herein with respect to these figures is for explanatory purposes as the invention extends beyond these limited embodiments.

[0028] FIG. 1 is a block diagram of a remote audio delivery system 100 according to one embodiment of the invention. The remote audio delivery system 100 includes an audio system 102 that produces an audio output. The audio system

102 is, for example, a television, a Compact Disc (CD) player, Digital Versatile Disk (DVD) player, a stereo, a computer with speakers etc. In one embodiment, the audio system 102 can also be referred to as an entertainment system. In one implementation, the audio system 102 is stationary – meaning that the audio system 102, although movable, generally remain in a fixed location. In any case, the audio output from the audio system 102 is supplied to a wireless transmission apparatus 104. In one implementation, the wireless transmission apparatus 104 is coupled to an audio output port (e.g., terminal, connector, receptacle, etc.) of the audio system 102. The coupling can be directly to the audio output port of the audio system 102 or can be coupled to the audio output port by way of a cable. In one embodiment, the wireless transmission apparatus 104 can also be referred to as a wireless audio adapter because it is able to adapt the audio system 102 for wireless audio delivery without requiring changes to the audio system 102.

[0029] The wireless transmission apparatus 104 receives the audio output from the audio system 102 and transmits the audio output over a wireless channel 105 (or wireless link) to a wireless receiver 106 of a personal audio device 107. The wireless channel 105 is typically a short range wireless link, for example, such as available using Bluetooth, WiFi or other dedicated frequency (e.g., 900 MHz, 2.4 GHz) techniques. As is well known, the wireless channel 105 carries the audio output, but the wireless channel 105 uses one or more frequencies not within the audio frequency range. The wireless receiver 106 receives the audio output that is transmitted by the wireless transmission apparatus 104 over the wireless channel 105. The received audio output is then supplied to control circuitry 108. The control circuitry 108 converts the received audio output into speaker drive signals. The speaker drive signals are then used to activate a directional speaker 110 which produces output sound. The output sound from the directional speaker 110 is directionally confined for enhanced privacy. Optionally, as discussed in detail below, the control circuitry 108 can also provide customization or personalization to the person and/or the environment.

[0030] The directionally confined output sound produced by the directional speaker 110 allows the user of the personal audio device 107 to hear the audio sound even though neither of the user's ears touches or coupled against the directional speaker 110. However, in one embodiment, the directional nature of the output sound is towards the user (e.g., user's ear(s)) and thus provides privacy by restricting the output sound to a confined directional area. In other words, bystanders in the vicinity of the personal audio device but not within the confined directional area would not be able to directly hear the output sound, or otherwise hear a significant portion of the output sound, produced by the directional speaker 110. The bystanders might be able to hear a degraded version of the output sound after it reflects from a surface. The reflected output sound, if any, that reaches the bystander would be at a reduced decibel level (e.g., at least a 20 dB reduction) making it difficult for bystanders to hear and understand the output sound. In another embodiment, the directional nature of the output sound, such as via an ultrasonic beam, is considered directed towards the ear as long as any portion of the beam, or the cone of the beam, is immediately proximate to, such as within 7 cm of, the ear. The direction of the beam does not have to be directed at the ear. It can even be orthogonal to the ear, such as propagating up from one's shoulder, substantially parallel to the face of the person.

[0031] In one embodiment, the directional speaker 110 is an ultrasonic speaker, and the control circuitry 208 converts the received audio output into ultrasonic drive signals that are used to drive the ultrasonic speaker. The ultrasonic drive signals are supplied to the ultrasonic speaker to generate ultrasonic output. The ultrasonic output is subsequently transformed, for example, by air, into audio output. In one embodiment, the frequency spectrum of the resulting audio output (after such transformation) is similar to the audio output from the audio system 102. In another embodiment, the frequency spectrum of the resulting audio output is altered so as to provide customized hearing (e.g., enhanced hearing), or to adapt to environmental conditions or physical conditions of the user.

[0032] FIG. 2 is a block diagram of a remote audio delivery system 200 according to another embodiment of the invention. The remote audio delivery system 200 includes an audio system 202 and a wireless transmitter 204. In one embodiment, the wireless transmitter 204 can also be referred to as a wireless audio adapter. It is able to adapt the audio system 202 for wireless audio delivery without requiring physical changes to the audio system 202. In one implementation, the wireless transmitter 204 is coupled to the audio system 202 via an audio output port of the audio system 202. Such coupling can be achieved by a connector alone or in combination with a cable. In another embodiment, the wireless transmitter 204 is integral and thus part of the audio system so that no connector or cable is necessary. The audio system 202 and the wireless transmitter 204 together form a wireless audio delivery system.

[0033] Audio output from the audio system 202 is supplied to the wireless transmitter 204 via the audio output port of the audio system 202 or other means. Then, the wireless transmitter 204 transmits the audio output over a wireless channel (wireless link) 205 to a wireless receiver 206 of a personal audio device 207. The received audio output at the wireless receiver 206 is then supplied to control circuitry 208. The control circuitry 208 can receive user information pertaining to the user from a data storage device 202. For example, the user information can pertain to an audio profile associated with the user. An audio profile contains or is based on hearing characteristics of an associated user. The user information can be stored in a data storage device 210. The data storage device 210 can be a dedicated or removable data storage medium. Examples of removable data storage medium include a memory card (Flash memory card, memory stick, credit card with data storage, PC card (PCMCIA), etc.).

[0034] The control circuitry 208 produces speaker drive signals that are used to drive a speaker 212. In this embodiment, the speaker drive signals are produced by the control circuitry 208 based upon not only the received audio output but also the user information. In other words, the control circuitry 208 can modify the drive signals being supplied to the speaker 212 based upon the user information. As

such, the audio sound being produced by the speaker 212 can be customized for (or personalized to) the user. For example, when the user information pertains to hearing characteristics and/or user preferences of the user, the control circuitry 208 is able to produce customized drive signals for the speaker 212 such that the resulting audio output by the speaker 212 is customized for the hearing characteristics and/or user preferences of the user.

[0035] The remote audio delivery system 200 shown in FIG. 2 can make use of customization of the audio output at the personal audio device 207. Note that, as shown in FIG. 2, the personal audio device 207 can include the wireless receiver 206, the control circuitry 208, the data storage device 210 and the speaker 212. Nevertheless, it should be noted that the customization could also be performed elsewhere. For example, the audio system 202 or the wireless transmitter 204 can further include control circuitry (not shown) that would obtain user information and then customize audio output prior to its transmission to the personal audio device 207. Such an implementation could provide centralized customization of the audio output for one or more personal audio devices.

[0036] FIG. 3 is a block diagram of a remote audio delivery system 300 according to yet another embodiment of the invention. The remote audio delivery system 300 includes an audio system 302, a wireless network 304, and personal audio devices 306 and 308. The wireless network 304 can be a wireless local area network, such as a Bluetooth or WiFi network. Here, the remote audio delivery system 300 illustrates that the audio system 302 can supply audio output to one or more personal audio devices 306 and 308 over a wireless network 304. The wireless network 304 can, for example, be used in the vicinity of a home or business. The audio output from the audio system 302 can be broadcast, multicast or unicast over the wireless network 304. In other words, the audio output from the audio system 302 can be directed to one or more of the personal audio devices 306 and 308. In one implementation, a different network address is associated with each of the personal audio devices, and thus the audio output can be transmitted to the appropriate one or more of the personal audio devices via the wireless network 304

using the associated network addresses. Although FIG. 3 illustrates only the personal audio devices 306 and 308, it should be understood that the remote audio delivery system 300 can support many personal audio devices, and such personal audio devices can be of the same type or of different types.

[0037] As described above, the wireless audio adapter 204 can be matched to the personal audio device 207. In other words, each wireless audio adapter can have a corresponding personal audio device.

[0038] In other embodiments, wireless signals from a wireless audio adapter 204 can be received by multiple personal audio devices. This can be done, for example, by broadcasting the audio output over a wireless channel and having the multiple personal audio devices tune to the wireless channel. The broadcast can be performed in the analog domain or in the digital domain. For the latter case, the broadcast can be performed in Layer 3 (e.g. IP multicast) or Layer 2 (e.g. IEEE 802.11). If personal customization is desired, each of the personal audio device 207 can be first initialized with the wireless audio adapter 204. The initializing process can be performed by requiring each audio device to transmit, wirelessly or through a wired connection, an identifier to the adapter. The adaptor then transmits the personalization information to the corresponding personal audio device according to the identifier. After the personalization information is received, the personal audio device can be configured accordingly and then start to receive the audio output.

[0039] In yet another embodiment, a personal audio device can be configured to be selected by a specific wireless audio adapter or an audio system. Such configurations would be applicable for after-market sales. The selection can be achieved through a number of approaches. For example, there can be switches on both the personal audio device and the wireless audio adapter, or both can have a number of channels. These switches or channels can be changed by users. When both set of switches or channels are matched, then the personal audio device is configured for the wireless audio adapter. Another approach is based on the Media Address Control (MAC) layer address, IP address or TCP or UDP port numbers. For

example, the personal audio device and the wireless audio adapter can agree on a specific TCP or UDP port number. They can then be configured to receive packets or signals from only that port. The personal audio device and the wireless audio adapter can also be identified by their specific addresses, such as IP addresses or MAC layer addresses.

[0040] FIG. 4 is a diagram of a building layout 400 illustrating use of several embodiments of the present invention. The building layout 400 illustrates a representative floor plan having a first room 402, second room 404 and a third room 406. The first room 402 includes an audio system (AS) 408 that includes a wireless transmission apparatus 410, or a wireless audio adapter, coupled to the audio system 408. The audio system 408 can use a traditional speaker and/or a directional speaker to direct audio sound to one or more of a first user (u-1) and a second user (u-2) located within the first room 401. Further, using the wireless transmission apparatus 410, the audio output from the audio system 408 can also be transmitted over a wireless channel (link) to one or more other users that are relatively nearby the wireless transmission apparatus 410. In other words, the type of the wireless channel sets the range. Typically, the range is relatively short, such as less than 400 meters. Hence, using the wireless channel, any one or more of a third user (u-3), a fourth user (u-4) and a fifth user (u-5) are able to hear the audio output by way of a personal audio device that receives the audio output over a wireless channel. As shown in FIG. 4, the fifth user (u-5) has a personal audio device 412 attached or proximate thereto. In one embodiment, the fifth user (u-5) wears the personal audio device 412, and is able to hear the audio output from the audio system 408 even though the fifth user (u-5) is, for example, outside of the building, such as in the backyard. The personal audio device 412 thus allows a remote user (e.g., u-5) to hear the audio output from the audio system 408 even though they are not within the same room or building as the audio system 408. So long as the remote user is within communication range of the wireless channel, the remote user can hear the audio output even as the remote user moves around. Since the third user (u-3) and the fourth user (u-5) do not have personal audio

devices, these users will not hear the audio output from the audio system 408 unless the audio output from the traditional speaker (if any) at the audio system 408 permeates the entire building layout 400 shown in FIG. 4.

[0041] In one embodiment, the personal audio devices can be wearable by users. Additional details on audio-related devices can be found, for example, in the above-referenced U.S. patent applications, which have been incorporated herein by reference.

[0042] Besides directionally constraining audio sound that is to be delivered to a user, the audio sound can optionally be additionally altered or modified in view of the user's hearing characteristics or preferences, or in view of the environment in the vicinity of the user.

[0043] FIG. 5 is a flow diagram of a remote audio delivery process 500 according to one embodiment of the invention. The remote audio delivery process 500 is, for example, performed by a remote audio delivery system, such as the remote audio delivery system 100, 200, or 300.

[0044] The remote audio delivery process 500 begins with audio signals being received 502 at a wireless audio adapter (or a wireless transmission apparatus). Typically, however, prior to receiving 502 the audio signals, the wireless audio adapter would have been attached to the audio system that initially provides the audio signals. In any case, the audio signals that are received 502 are thereafter wirelessly transmitted 504 to a personal audio device. Typically, the audio signals are wirelessly transmitted a predetermined personal audio device. In other words, the wireless audio adapter can be configured to transmit audio signals to be wirelessly received by a predetermined personal audio device. However, the audio signals may be transmitted to a plurality of predetermined personal audio devices. To direct the audio signals to be received by the appropriate one or more personal audio devices, a number of methods can be used, for example, predetermined frequencies, encoding and/or network identifiers (e.g., addresses).

[0045] After the audio signals are wirelessly transmitted 504, the audio signals are received 506 at the personal audio device. At this point, additional processing

can be performed to enhance the resulting audio sound that will eventually be delivered to a user of the personal audio device. A decision 508 determines whether user personalization is to be performed. When the decision 508 determines that user personalization is to be performed, then the audio signals are modified 510 based on user information. For example, the user information can be provided by a data storage device, such as the data storage device 212 as illustrated in FIG. 2.

[0046] In one implementation, the user information is related to an audio profile that pertains to the hearing characteristics of the user. In another implementation, the user information is related to the physical conditions of the user. Such physical conditions can be detected by a sensor, which can be embedded in the personal audio device, or wirelessly supplied to the personal audio device. As an example, if the user is sleeping, the volume of the output sound should be reduced or even turned off. Determining physical conditions can be dynamically performed. For example, a sensor can keep track of the user's heart beat and identify patterns accordingly.

[0047] Following the modifying 510 or directly following the decision 508 when user personalization is not to be performed, a decision 512 determines whether environmental adjustments are to be performed. When the decision 512 determines that environmental adjustments are to be performed, the audio signals are modified 514 based on environmental characteristics. Such environmental characteristics can be detected or sensed by the personal audio device, which can include one or more environmental sensors. As an example, the environmental sensor(s) can measure ambient or background noise. The environmental characteristics could also be wirelessly transmitted to the personal audio device.

[0048] Following the modifying 514 based on environmental characteristics or directly following the decision 512 when no environmental adjustments are to be made, the audio signals are converted 516 to ultrasonic drive signals. The ultrasonic drive signals are then used to drive 518 a directional speaker that, in turn, outputs ultrasonic sound in a directionally constrained manner. The ultrasonic sound is directed to the user of the personal audio device and interacts with air such

that audio sound is present when the acoustic output from the directional speaker is in the vicinity of the head (or ears) of the user. However, since the ultrasonic (and resulting audio) sound produced is directionally constrained, it is delivered in a targeted way to the user. Thus, other users in the vicinity of the user will not hear any substantial amount of the audio sound, and therefore will not be disturbed thereby.

[0049] FIG. 6A is a flow diagram of an environmental accommodation process 600 according to one embodiment of the invention. The environmental accommodation process 600 determines 602 environmental characteristics. In one implementation, the environmental characteristics can pertain to measured sound (e.g., noise) levels at the vicinity of the user. The sound levels can be measured by a pickup device (e.g., microphone) at the vicinity of the user. The pickup device can be incorporated in the personal audio device. In another implementation, the environmental characteristics can pertain to estimated sound (e.g., noise) levels at the vicinity of the user. The sound levels at the vicinity of the user can be estimated based on a position of the user/device and a linking of position with an estimated sound level for the particular environment. The position of the user can, for example, be determined by GPS or network triangulation. After the environmental accommodation process 600 determines 602 the environmental characteristics, the audio signals are modified based on the environmental characteristics. For example, if the user were in an area with a lot of noise (e.g., ambient noise), such as a confined space with various persons or where construction noise is present, the audio signals could be processed to attempt to suppress (or cancel) the unwanted noise and/or the audio signals (e.g., in a desired frequency range) could be amplified. In the case of amplification, if noise levels are excessive, the amplification might not occur as the user might not be able to safely hear the desired audio signals. In other words, there can be a limit to the amount of amplification and there can be negative amplification (even complete blockage) when excessive noise levels are present. Noise suppression and amplification can be achieved through conventional digital signal processing, amplification and/or filtering. The

environmental accommodation process 600 can, for example, be performed periodically or for every new audio stream.

[0050] A user might have a hearing profile that contains the user's hearing characteristics. Hence, the audio sound provided to the user can optionally be customized or personalized to the user by altering or modifying the audio signals in view of the user's hearing characteristics. By customizing or personalizing the audio signals to the user, the audio output can be enhanced for the benefit of the user. Additional details on hearing enhancement can be found, for example, in U.S. Patent Application No. _____, filed concurrently, and entitled, "DIRECTIONAL HEARING ENHANCEMENT SYSTEMS," which has been incorporated herein by reference.

[0051] FIG. 6B is a flow diagram of audio personalization process 620 according to one embodiment of the invention. The audio personalization process 620 retrieves 622 an audio profile associated with the user. The hearing profile contains information that specifies the user's hearing characteristics. For example, the hearing characteristics may have been acquired by the user taking a hearing test. Then, the audio signals are modified 624 based on the audio profile associated with the user.

[0052] The hearing profile can be supplied to a personal audio device or to a directional audio delivery system that performs the personalization process 620 in a variety of different ways. For example, the audio profile can be electronically provided to the personal audio device or the directional audio delivery system through a network. As another example, the audio profile can be provided by way of a removable data storage device (e.g., memory card). Additional details on audio profiles and personalization can be found in the above-referenced U.S. patent applications, which have been incorporated herein by reference.

[0053] The environmental accommodation process 600 and/or the audio personalization process 620 can optionally be performed together with any of the processes used to produce the directionally confined output sound, as discussed above. For example, the environmental accommodation process 600 and/or the audio personalization process 620 can optionally be performed together with any of

the remote audio delivery systems 100, 200 or 300 embodiments discussed above with respect to FIGs. 1, 2 or 3, or the remote audio delivery process 500 discussed above in FIG. 5. With respect to the remote audio delivery process 500 shown in FIG. 5, the environmental accommodation process 600 or the audio personalization process 620 can be performed at the operation 514 or the operation 510, respectively.

[0054] FIG. 7A is a perspective diagram of an ultrasonic transducer 700 according to one embodiment of the invention. The ultrasonic transducer 700 can implement a directional speaker as discussed herein. The ultrasonic transducer 700 produces the ultrasonic sound utilized as noted above.

[0055] FIG. 7B is a diagram that illustrates the ultrasonic transducer 700 with its beam 704 being produced to output ultrasonic sound. The beam 704 can have its attributes, such as its beam width, varied in a variety of different ways. Additional details on the ultrasonic transducer 700 can be found, for example, in the above-referenced U.S. patent applications, which have been incorporated herein by reference.

[0056] An audio system of the present invention can include or couple to a set top box that includes the wireless audio adapter or permits attachment thereto. A set-top box enables a television set to receive and decode digital television broadcasts. Typically, the set-top box is positioned proximate to the television set.

[0057] FIG. 8 is a perspective diagram of an audio system that provides directional audio delivery to interested users. The figure illustrates an audio system 800 that includes a television 802, a set-top box 804 and a directional speaker 806. The directional speaker 806 provides delivery of audio signals in a constrained direction. Further, the directionally constrained audio signals can be controlled as to the target distance for its users as well as for the width of the resulting audio signals. The directional speaker 806 outputs ultrasonic sound by way of an emitter surface 808. The emitter surface 808 can be comprised of a single or multiple ultrasonic transducers.

[0058] Furthermore, in one embodiment, the directional speaker 806 can be mounted to the set-top box 804 such that it is able to be rotated with respect to the set-top box 804 as well as the television 802. The rotation of the directional speaker 806 causes a change in the direction in which the directionally constrained audio signals are delivered. In another embodiment, the directional speaker 806 can control the direction in which the directionally constrained audio signals are delivered, such as by beam steering techniques. Additional details on different embodiments of set-top boxes can be found, for example, in the above-referenced U.S. patent applications, which have been incorporated herein by reference.

[0059] Besides the ability of the audio system 800 to include optionally directional speaker 806, the audio system 800 illustrated in FIG. 8 can utilize the various methods and processes discussed above to provide wireless audio delivery to personal audio devices. More particularly, the set-top box 804 can also include a wireless audio adapter as discussed above. For example, in one embodiment, the set-top box 804 can include the wireless transmission apparatus 104 (and possibly the audio system 102). In another embodiment, the set-top box 804 can include the wireless transmitter 204 (and possibly the audio system 202) of the remote audio delivery system 200. Optionally, the set-top box with directional speakers shown in FIG. 8 is able to transform conventional televisions into televisions whose audio systems have directional audio delivery (as well as wireless delivery to personal audio devices).

[0060] In one embodiment, the ultrasonic beam is considered directed towards the ear as long as any portion of the beam, or the cone of the beam, is immediately proximate to, such as within 7cm of, the ear. The direction of the beam does not have to be directed at the ear. It can even be orthogonal to the ear, such as propagating up from one's shoulder, substantially parallel to the face of the person.

[0061] The various embodiments, implementations and features of the invention noted above can be combined in various ways or used separately. Those skilled in the art will understand from the description that the invention can be

equally applied to or used in other various different settings with respect to various combinations, embodiments, implementations or features provided in the description herein.

[0062] The invention can be implemented in software, hardware or a combination of hardware and software. A number of embodiments of the invention can also be embodied as computer readable code on a computer readable medium. The computer readable medium is any data storage device that can store data which can thereafter be read by a computer system. Examples of the computer readable medium include read-only memory, random-access memory, CD-ROMs, magnetic tape, optical data storage devices, and carrier waves. The computer readable medium can also be distributed over network-coupled computer systems so that the computer readable code is stored and executed in a distributed fashion.

[0063] The advantages of the invention are numerous. Different embodiments or implementations may yield different advantages. One advantage of the invention is that audio output from an audio system can be wirelessly transmitted to a personal audio device without requiring modification to the audio system. Another advantage of the invention is that audio output produced for a user by a personal audio device can be directionally constrained so as to provide directional audio delivery. The directionally constrained audio output can provide less disturbance to others in the vicinity who are not desirous of hearing the audio output. Still another advantage of the invention is that audio output produced for a user by a personal audio device can be customized for the user and/or to the environment of the user.

[0064] Numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those skilled in the art that the invention may be practiced without these specific details. The description and representation herein are the common meanings used by those experienced or skilled in the art to most effectively convey the substance of their work to others skilled in the art. In other instances, well-known methods,

procedures, components, and circuitry have not been described in detail to avoid unnecessarily obscuring aspects of the present invention.

[0065] In the foregoing description, reference to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment can be included in at least one embodiment of the invention. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments. Further, the order of blocks in process flowcharts or diagrams representing one or more embodiments of the invention do not inherently indicate any particular order nor imply any limitations in the invention.

[0066] The many features and advantages of the present invention are apparent from the written description and, thus, it is intended by the appended claims to cover all such features and advantages of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation as illustrated and described. Hence, all suitable modifications and equivalents may be resorted to as falling within the scope of the invention.

What is claimed is: